Balancing renewables by demand side management: local and global potential of loads

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***Abstract*— Applying Demand Side Management (DSM) for balancing renewable energy sources (RES), makes it possible to increase energy generation of RES without the need for expensive (spinning) reserve on fossil power plants. The potential of DSM has already been demonstrated for peak shaving, but not for balancing RES.**

After classifying the loads with their specific constraints for DSM , this paper calculates the potential of DSM for households in Belgium. The calculation is based on measured load capabilities, using laboratory measured profiles of each type of load. The potential has been calculated on a local basis (per dwelling) as well as on a global basis (4.5 million households in Belgium). The calculation also considers the influence of including small and medium enterprises (SME's). To illustrate the importance of DSM, projections for the years 2020 and 2050 are made. These projections make clear that the potential of DSM should be taken into account in decisions on subsidies for RES. The paper is supported by numerical data for the Belgian situation.

***Index Terms*— active demand side management, dynamic load, balancing, RES, Smart Grid.**

I. Introduction

To facilitate the increase in renewable energy sources (RES) in a cost effective way, a more dynamic and intelligent utilization and operation of the grid will be needed, often referred to as the "Smart Grid" concept [1], [2], [3].

Most of the RES are intermittent in nature which makes balancing of generation and load more difficult. The dominating part of the intermittency cost will be the balancing cost due to imperfect forecasts (load, wind, sun, …)[4][5]. Balancing generation and load can be done:

- by using flexible generation,
- by using storage or buffer capacity (typically batteries or pumped hydro power) or
- by Demand Side Management (DSM), exploiting controllable loads.

Using flexible generation is the traditional approach for balancing. However, the share of flexible generation in total generation capacity will decrease by 2050 with increasing renewable sources and increasing scarceness of fossil fuels. Therefore other balancing methods should take a larger part of the balancing system. The advent of Smart Grids has put the latter two options forward as potential techno-economic alternatives to flexible generation. The potential of buffer capacity is clear. A certain power is available during a certain period which can be used when necessary. Rudimentary algorithms are already used today to manage these buffer capacities (e.g. pumped hydro). However, installing buffer capacity requires a large investment cost. DSM on the other hand exploits controllable loads already present in the grid and does not require large investments in hardware. The investment in ICT and control for DSM might be higher than using buffer capacity, but having measurements and control on local generation and demand increases the reliability. Moreover DSM is also relatively fast: [6] mentions a reaction time of 90 seconds for full response, whereas generators usually have a 10-minute ramp time. This means that DSM could not only make loads "generation-following", but could also take a large part of the necessary balancing power (regulation ancillary service) and primary frequency control, limiting the (expensive) spinning reserve and peak power plants [7]. DSM can have different goals [8]. In this paper DSM is considered to actively follow varying generation. A lot of alternative expressions are used for this active control going from demand dispatch [7] to flexible load shape [8] and price-responsive demand [9]. Here, DSM is kept as global term. But the potential for DSM is hard to determine. This paper calculates the potential of DSM for the Belgian situation, focusing on households, although also small and medium enterprises (SME's) are considered. Section II briefly describes current implementation of DSM and future evolution of implementing DSM and related financial profit. Section III discusses the profiles and the constraints of each type of load for use in DSM and summarizes per type of load the most important conclusions. A more detailed discussion about how the load profiles and constraints are determined can be found in [10]. Section IV determines the current potential of DSM for balancing on a minute (or larger e.g. 5 minute, 15 minute values) base. This paper does not consider DSM for primary frequency control. Based on current technologies, projections for the years 2020 and 2050 have been made. The results show that currently DSM already has a large potential for balancing RES, and that this potential significantly increases in the

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future.

II. IMPLEMENTING DSM

DSM is already used in a rudimentary way for peak shaving [6], [11], [12], [13], and its general potential has already been simulated [14], [15], [16], [17]. Because these simulations work with basic, simple load models, further research on the potential of real applications is needed to understand the full potential of DSM, and to limit the rebound effect of switching off loads. To that end, the authors have measured and discussed more detailed load profiles of controllable loads in residential and tertiary sector: "how much energy is buffered in a controllable load at a given time", "over what time interval can the load be shifted", etc. [10]. These more detailed load profiles bring the potential of the loads fully into account. For example with the more detailed model of a freezer it is possible to buffer electricity for 20 hours (cooling from -18°C to -28°C) instead of only a delayed start of 15 minutes in the simple load model. For all thermal processes similar improvements have been realized with the more detailed models described in [10].

Today, implementation of DSM is centrally controlled. With a smart meter, DSM could be applied on a shorter timeframe also for other loads than the currently used heating appliances. Pump appliances (e.g. ponds) are well suited for this, while no big changes have to be made to these appliances. For other appliances (e.g. ventilation, air conditioning, …) such a direct, central control is less acceptable. Real-time pricing (RTP), based on wind- and solar predictions communicated via a smart meter gives the opportunity to actively control loads locally and automatically which is the scope of [18]. The (aggregated) load will have a preferred operating point (POP) with a regulation up and down limit. The customers will be flexible but at the end they retain overall control [19], albeit at a certain cost depending on the (balancing) market at that moment.

To illustrate the usefulness of such a control, the authors have discussed the financial potential of a 50kW PV installation in Belgium [20]. They conclude that the profit of DSM for the end consumer is inversely proportional to the subsidies of PV (or RES in general). When the achieved flexible power could be sold as regulation power, the economic value of DSM even rises significantly (e.g. 35 US$/MW per hour) [7].

III. USING LOADS FOR DSM

For industry, the application of DSM should be considered per company or process. Most companies have company-specific constraints and industry will consider DSM from the moment that market mechanisms (e.g. real time pricing) are available and sufficiently profitable to risk potential negative effects on their business. For households and SME's on the other hand, appliances permit a more generic approach. Because households and SME's represent up to 50% of total electricity consumption in Belgium and the rest of Europe [11] and (centrally or price) controlled DSM and load shedding are not yet implemented, the potential is worthwhile to investigate.

A. *Classifying loads*

Loads can be divided into two main groups; controllable and uncontrollable loads. Controllable loads are loads that can be managed automatically. Uncontrollable loads are loads of which the use is completely determined by the end user. Nevertheless these uncontrollable loads can have some flexibility, but this flexibility depends exclusively on user operations (e.g. brown good).

1) *Controllable loads*

Controllable loads exist in different types:

- Buffer capacity (e.g. cold, heat, battery)
- Time shift (e.g. washing machine)
- Different comfort level (e.g. air conditioning, ventilation, lighting to a limited extent)

The use of buffer capacity can lead to an increased energy consumption (e.g. for a freezer up to 65% when keeping it constantly at -28°C instead of -18°C) [21]. The applied buffer (extra cooling, extra heating, …) should therefore be limited to strictly necessary levels. To minimize extra energy consumption predictions of production and demand are thus essential to determine the minimum necessary buffer capacity, minimizing extra energy consumption. One can note that if freezers consume more energy to create a buffer capacity, this is not a sustainable solution. On the other hand, exploiting this buffer capacity can facilitate more RES without the need for more installed balancing power (spinning reserve, peak plants, storage), making the use of the buffer capacity in that case sustainable and affordable. Extra balancing power results after all in large capital expenses and also in an energy loss (lower efficiency for spinning reserve, storage systems also have limited efficiencies). Using the buffer capacity not only avoids capital costs, it can also deliver the end user (owner of the appliance) some profit. Using the buffer capacity, energy cost can already today be decreased with 16% (depending on the supplier) for current double tariff structures in Belgium [21]. The energy consumption increases with (only) 20 % for a buffer of 15 hours, which seems acceptable compared to the efficiency of pumped hydro and batteries.

Shifting loads with a certain time shift does not increase the total energy consumption. Loads that can be shifted automatically to periods of high local renewable production should be looked at before creating a buffer in other loads. Predictions of RES and knowledge of the use of loads are therefore indispensable.

The comfort level of some loads, especially building related loads such as heating, ventilation and air conditioning (HVAC), can automatically be changed between certain thresholds without complaints. For ventilation a maximum of for example 1000ppm CO_2 can be imposed. At moments of cheap (local) energy, ventilation can be forced to achieve lower CO_2 levels in order to be able to reduce ventilation with high energy prices. For heating and cooling a temperature variation, e.g. 2°C, can be allowed, depending on the residents' desires. If more flexibility is necessary, not only the building inertia could be considered but extra buffer capacity, like ice accumulation or hot water storage tanks, can be added. As mentioned above, energy consumption will rise using this buffer, but energy cost and CO_2 emissions can decrease when this buffer allows more RES. The extra consumption of the buffer capacity could be limited when people allow a larger temperature variation. Reducing light levels from e.g. 500 lux to 300 lux automatically could make people aware of energy shortage which could make them accept a larger temperature variation. Of course the user should have end control, leading to the desired comfort level, but being aware of possible peak prices when limited flexibility is allowed.

2) Uncontrollable loads

If prices rise above a certain (psychological) threshold, people may even be willing to completely switch off certain uncontrollable appliances (hand in even more comfort). Because this threshold differs from person to person, loads will be switched off gradually which benefits grid stability. A temporary lower comfort level (due to high electricity prices) leads to a lower end consumption because there is no rebound effect. For example when people switch off ambient lights in periods of high electricity prices, they will not compensate for the period of reduced light level.

Switching off uncontrollable loads is normally not automated. People decide themselves whether they want to switch off certain uncontrollable loads or not. Reducing light levels automatically with high energy prices can be automated and can make people even more conscious of these high prices, leading to a further reduction in consumption of uncontrollable loads such as brown good (HIFI, TV, ,…) or cooking devices.

B. Load constraints

Switching loads has to take the nature of the load into account. Some loads can be switched at any time, other loads (like air conditioners, freezers, …) require a certain minimum switch off period. They cannot be switched on during a determined time after being switched off. Control strategies which want to balance for example 15 minute values have to take this into account. The boundaries of a buffer capacity can be represented by means of a 'must on' or a 'must off' state. A boiler of which the temperature approaches boiling temperature has to be switched off for security reasons. A freezer, on the other hand, of which the temperature approaches -18°C has to be switched on for food conservation.

Short time variations (seconds) are therefore not considered to be compensated by loads. Furthermore, using loads for very rapid changes might lead to excessive wear and tear for loads and switching devices. Short-time variations are assumed to be partly compensated by the inertia of the system and for the rest they may be compensated by fast energy storage such as supercapacitors or batteries in combination with island supporting invertors. Furthermore, using loads for very rapid changes might lead to excessive wear and tear for some of these loads. The potential for DSM is thus mainly on a 15 minute basis and if fast energy storage is used to compensate fast changes, DSM can limit the size of this fast energy storage.

IV. Local and global potential for DSM

To determine the potential of one dwelling or one small or medium-sized enterprise (SME), Table 1 lists a typical value of the nominal power and maximum 'on-' and 'off times' of the most promising controllable appliances considered in [10]. For building-related appliances an office space for 15 persons has been considered. For each person a surface of 11 m² has been taken. This means that the total office surface is approximately equal to the surface of a 3 bedroom-dwelling in Belgium. The power of the heat pump can thus be the same as that of an average dwelling. The ventilation has to provide 54 m³/h per person (to guarantee IDA class 2 [22]) and consumes approximately 0.7W per m³/h. This leads to 550W for SME's. For dwellings the ventilation has been calculated for fewer persons resulting in approximately 100W. The air conditioner consumes approximately 50W/m² and for lighting the guidance value of 2.5W/m²/100 lux leads to the 2000W installed power guaranteeing 500 lux.

Table 1 Potential for DSM of controllable loads

Appliance	Nominal power (W)	Maximum off time (hours)	Maximum on time (hours)	Installed estimated power (MW) for 4,5 million dwellings in Belgium			Normal operating hours
				2011	2020	2050	
Freezer	100	30	20	450	450	450	8/day
Refrigerator	100	0.25	0.25	450	450	450	8/day
Air conditioning	4000	1	1	200	2000	2000	500/summer
Electric boiler	2000	24	8	2400	3600	8000	3/night
Heat pump	4000	16	8	40	400	16000	1000/winter
Ventilation	100	1	cont.	10	100	450	24/day
Laptop	100	6	3	450	450	450	4/day
EV	3000	24	8	0.13	300	12000	4/day
Water	60 – …	24	24	30	60	120	1...24/day
Dish washer	2000	19	2	3600	5400	7200	170 cycles/year
Lighting	2000	reduced comfort	cont.	9000	9000	9000	1…10/day

The table further gives an estimated installed power for each appliance for the 4.5 million households in Belgium for 2011, 2020 and 2050.

A. Data for 2011 and projections for 2020 and 2050

Nowadays, almost every household owns a freezer and a refrigerator, resulting in 450MW total installed power. In 2020 and 2050 this installed power is assumed to be the same because the number and the energy efficiency of those devices will not change much. Demographic growth for all appliances is considered zero in order to compare the figures with the 2010 peak load. The nominal power of an air conditioner for an SME is calculated at 8kW (50W/m² for an office of 15 persons). To calculate the total installed power for all households in Belgium, only 1% of all households is considered to have an air conditioner limited to 4kW in 2011. This is estimated to increase (with increasing comfort requirements), to 10% of all households in 2020 and 2050 (stabilizing because of rational energy use and passive houses).

In 2011 almost 1.2 million households have an electric boiler with an estimated average nominal power of 2000W. This results in 2.4GW for all households. It is estimated that in 2020 1.8 million households will have an electric boiler, but half of these boilers only as a secondary boiler combined with thermal solar panels (limiting the potential for DSM). This further increases to 4 million in 2050, with all boilers operating as secondary system. For heat pumps it is assumed that 10,000 dwellings (10% of the new dwellings over the last two years) have a heat pump of 4kW electric power installed. This results in 40MW for all households in 2011. For 2020 the total number of households with a heat pump is assumed to increase with 20% of all new houses over this period. In 2050 practically every dwelling has to be heated electrically (heat pump or other techniques) to become CO_2-lean.

New buildings have the obligation to implement ventilation. For 2011 it is assumed that over the last two years every new building (100,000 over the last two years in Belgium) has implemented mechanical ventilation of 100W resulting in 10MW total installed power. In 2020 this can increase up to 100MW taking into account the new buildings and renovation, leading to 450MW in 2050 when every dwelling will have mechanical ventilation.

Assuming that, on average, every household has one laptop, the total installed power for 2011 comes at 450MW. For the values for 2020 and 2050 the number of active laptops is believed to stay stable. The number of (plug-in hybrid) electric vehicles ((PH)EV's) on the other hand is limited in 2011 to 43 [23] leading to 129kW 'installed' power (only normal charging at 3kW each is considered). The number of (PH)EV's is expected to increase exponentially. It is believed that the number of vehicles that can be electrically charged will increase up to 100,000 in 2020 and further up to 4 million in 2050. Perhaps not every household will have an EV, but others can have multiple EV's.

For the number of water pumps no data is available in Belgium. In order to have an idea of the potential, 500,000 pond pumps of 60W each are estimated for 2011. The figure is doubled for 2020 and 2050. The number of ponds will not necessarily increase, but the figure takes swimming pools (with larger pumps) gradually into account. With these estimations it is clear that water pumps do not have a significant share in the total potential for DSM of households and SME's. In industry and the agricultural sector on the other hand, the potential of water pumps can be higher.

In 2011, 40% of all households has a dishwasher [4] resulting in 3.6GW total installed power in 2011. It is assumed that the number of households having a dishwasher will increase to 60% in 2020 and 80% in 2050.

Despite the high value in 2011, the installed power for lighting is estimated to be constant in time. Average lighting efficiency will increase, but the demand for light is assumed to increase as well.

B. Potential for Belgium for all households and availability

Using the loads listed in Table 1, the total available power for DSM represented by all households in Belgium (4.5 million) has been calculated and the results are listed in Table 2. The table considers the available peak power on the one hand and the power available during eight hours or more on the other hand. Peak power represents the maximum power that can be switched on (or off) instantaneously. More interesting is the power available during eight or more hours ('Maximum on time' >= 8hours). Longer periods of renewable energy can be filled in with this power, after which these loads also do not need energy for a long period ('Maximum off time' >= 8hours). The peak power and the power available during eight or more hours has been determined for the year 2011 and projections have been made for the years 2020 and 2050.

Not all loads are available during the whole year. Therefore the table considers four different periods in a year; 'winter day', 'summer cloudy day', 'summer sunny day' and 'Mid season'. The distinction between 'summer cloudy day' and 'summer sunny day' has been made because domestic hot water (DHW) will be obtained in a different way. On a sunny day in summer, DHW can be made by means of a solar boiler. On a cloudy (rainy) day, DHW will have to be made with electricity. Because a building either has to be heated (winter equivalent) or cooled (summer equivalent) and because the non-building related appliances (e.g. EV, dishwasher, …) are not depending on season, spring and autumn can be represented by the figures of winter or summer depending on exterior temperature. Days where no heating nor cooling is necessary and DHW can be fulfilled by solar thermal boiler and no lighting is necessary are days with the lowest potential. These days are represented by the figures mentioned with "Mid season".

To determine whether the loads are available in 'winter', 'summer cloudy', 'summer sunny day' or 'mid season', the normal operating hours of the appliances in Table 1 are necessary to determine the global potential in Table 2. For example, both freezers and refrigerators have typical duty cycles of 1/3. Freezers however have large 'on' and 'off' times whereas refrigerators are limited in buffer capacity. Freezers are thus practically always available for DSM, while refrigerators are practically not suited for DSM and are not included in the calculated available (peak) power for DSM. Air conditioners are only available during hot summer days and thus perfectly suitable to match PV power. Heat pumps (or other types of electric heating) on the contrary are only available (approximately 1000 hours per year) during winter days and are not available during summer.

Electric boilers are available during the whole year (3 up to 8 hours per day) but will only be used when no sun is available for the solar boiler in 2050 (winter and cloudy day in summer in 2050). For 2011 it is assumed that electric boilers are always included because solar boilers are not yet installed in dwellings with electric boilers. For 2020 it is assumed that half of the electric boilers also have a solar boiler as primary system. So on ‘summer sunny days’ only the boilers without solar boiler are taken into account. In the simulations for 2050 it is assumed that if an electric boiler is available, also a solar boiler is available.

Ventilation, laptops, electric vehicles, water pumps, dish washer (and washing machine, dryer), are available during the whole year. Washing machines and dryers are not taken into account, but the nominal power of dish washers is fully taken into account. Given the limited operating times of these appliances, it is reasonable to assume that on average one of these appliances (washing machine, dryer or dish washer) is ‘ready to operate’ and thus the calculated available power is not exaggerated. The possible peak power for DSM can even be much larger when all these appliances operate at the same time.

For laptops and electric vehicles the normal operating hours are limited to approximately four hours a day. Once a laptop has been charged it can operate for the next four hours (depending on the battery) without extra energy. For (PH)EV’s a charging time of also four hours a day has been considered. 80% of the Europeans travel less than 40 km a day [24]. The necessary energy for this route can be delivered by a normal 230V outlet within four hours in an EV. This is the typical charging time to charge the battery up to 80%. Nevertheless, in case of extra available energy, the battery can further be charged up to 100%, totaling the possible charging time up to eight hours.

Lighting is not fully taken into account. The end consumer normally wants to keep the end control of his lighting comfort. Nevertheless, it seems fair to take 10% of installed power into account for ‘summer cloudy days’ and ‘winter days’.

Table 2 Global potential for DSM for 4.5 million dwellings in Belgium

	2012	2020	2050	
Available peak power (MW) for DSM	7880	11660	45570	**Winter**
	8040	13260	31570	**Summer cloudy day**
	7100	10560	22670	**Summer sunny day**
	6940	8560	20670	**Mid season**
Peak load Belgium 2010	14391 MW			
Base load Belgium 2010	6278MW			
Available power (MW) for DSM (>= 8hours)	3830	5810	37920	**Winter**
	3790	5410	21920	**Summer cloudy day**
	2890	2710	13020	**Summer sunny day**
	2890	2710	13020	**Mid season**

The results in Table 2 give an indication of the potential of all households in Belgium. The available peak power for DSM in 2011 is between 7 and 8 GW, not really depending on seasons. In 2020, available peak power is approximately 11GW with a maximum of 13 GW on summer cloudy days because of lighting and electric boilers. The available peak power in 2050 depends on the season. The highest available power of 45GW is seen in winter because of electric boilers and electric space heating. Mid season represent the lowest available peak power (but still 20GW) because of the low amount of air conditioners and no electrical heat demand. The available power for DSM in summer in 2050 is in fact underestimated because it is assumed that only 10% of the households will have air conditioning. If heat pumps are actually as much installed as assumed in Table 1, people will use these heat pumps also for cooling. Nevertheless, the possible (peak) power for DSM originating from households is significant, certainly compared to the peak demand of 2010 [25]. The peak demand of 2010 is taken instead of the peak demand of 2011, because peak demand of 2010 was the highest over the last nine years. This peak demand of 2010 is also considered in Belgian governmental perspective scenario’s.

Operating hours of the peak power are limited, To have a better idea of the power available for buffering renewable energy for a longer period, another calculation including the appliances with possible operating hours more than eight hours has been executed. Table 2 also lists these results. The values for the available power are much lower than the corresponding possible peak powers. But towards 2050, the buffer capacity increases significantly dominated by electric vehicles and electric heating (space heating and DHW). In 2011, the power for DSM available for more than eight hours represents practically 50% of the 2010 base load. This increases to almost 100% of the 2010 base load in 2020 up to more than 200% in 2050 (even 600% in winter). If the transition to a CO_2-lean society will be made, it is clear that electricity consumption will rise. The 2010 peak- and base load therefore do not represent the 2020 and 2050 peak- and base load. With DSM, load profiles will follow generation. So, peak and base load will mainly depend on the generation of the RES. The 2010 peak and base load are only given to illustrate the potential of DSM for Belgium.

The figures for 2050 are determined in assumption that transportation and heating will shift from fossil fuel to mainly electricity driven in order to achieve the 2050 CO_2-lean goal. Whether this will be the case, is still an open question and predictions are difficult to make. Therefore the authors only take into account current available technology (like heat pumps, (PH)EV’s, solar thermal systems,…). For storage, the authors assume that technology will further develop to affordable, reliable and safe components in different applications. The main uncertainty is about how fast the transition will take place. The figures in Table 2 are determined assuming that 2050 goals will be met. Because this assumption might be too optimistic, Table 3 compares the end results for 2050 with different penetration rates for EV's and electric heat (room and DHW). In a pessimistic scenario only 25% of all households have electric cars and electric heat. The available peak power for DSM reduces to half of that in the most optimistic scenario in which 90% of all households have made the transition to electric transport and heat. The power available during eight or more hours in the pessimistic scenario is only one third of that in the most optimistic scenario. Although the figures of the pessimistic scenario are significantly lower than the figures of the optimistic scenario, the potential of DSM remains substantial.

Table 3 Influence of percentage electrification of transport and heat on 2050 results

Penetration electrification transport and heat	25%	50%	90%	
Available peak power (MW) for DSM	18570	27570	45570	Winter
	16570	21570	31570	Summer cloudy day
	13670	16670	22670	Summer sunny day
	12570	15570	21570	Mid season
Available power (MW) for DSM (>= 8hours)	10920	19920	37920	Winter
	6920	11920	21920	Summer cloudy day
	4020	7020	13020	Summer sunny day
	4920	7920	13920	Mid season

C. Potential for Belgium including SME's

Table 2 only lists the available power for DSM for the 4.5 million households in Belgium. [26] gives the evolution of total yearly energy consumption for households and 'equally treated' (among others SME's) on the one hand and for the industrial sector on the other hand. The figures show that total electricity consumption of households together with the equally treated is practically the same as that of industry. This is true for Belgium and also for the rest of Europe [27].

[26] further shows that households consume practically as much as the equally treated. If the SME's are also taken into account, the possible effect (larger power, but especially enlarging buffer times because normal operating hours are largely complementary) could be doubled because possible loads for DSM are similar to that of households and SME's typically have more air conditioners and ventilation installed, which are more interesting than washing machines and dryers in view of DSM.

Electrification of the transport sector will result in a significant increase in electricity consumption. According to [26], the yearly total energy consumption of transportation is 1.3 times total electricity demand. This does not mean that electricity demand will double, because electric vehicles (EV's) are more energy efficient than conventional vehicles with internal combustion engines. The impact on peak load could be reduced when EV's are intelligently charged [28], but still it is difficult to estimate future peak loads, therefore table 2 only gives the peak load of 2010.

D. Recommended RES mix

From Table 2 it is clear that the available peak power as well as the available power for long periods (more than eight hours) of the controllable loads is highest in winter for Belgium. This is characteristic for the northern European countries where heating takes a significant part of the controllable power. Fortunately this region is characterized with more wind energy compared to PV energy. For more southern countries the controllable load will mostly be determined by cooling in summer. These countries also have a higher potential PV power compared to the northern countries. This should be taken into account in subsidies for RES. To balance the RES with the load locally (on building level or on a higher but still regional level) the right type of RES (or the right mix in RES) should be implemented. For this reason Belgian policy, for example, could stimulate more wind energy.

V. CONCLUSIONS

This paper gives an overview of the available power for DSM in Belgium. The calculations are based on measurements and collected data. Also predictions for 2020 and 2050 have been made. Table 1 lists per load the maximum on- and off-time and the possible available power for DSM in 2011, 2020 and 2050. For loads where the buffer capacity can easily be extended (e.g. larger hot water tank with heat pump), the figures represent an assumed acceptable average installation. Buffer capacities depend in general on use and scale of the appliances but even with moderate assumptions, the potential for DSM of the considered appliances is significant. The available peak power for DSM in 2050 becomes even up to 3 times higher (depending on season) than the 2010 peak demand. DSM power which is available for more than eight hours increases from approximately 3GW today up to 13GW in summer and 38GW in winter in 2050.

The assumptions for 2050 are made given the current technology and expected future evolutions. The absolute values of the projections for 2050 are of course estimations, but to achieve 2050 goals, these figures make clear that DSM can represent an increasing contribution in balancing RES. Already today, DSM has a significant potential: peak power and power available for more than eight hours respectively represent almost 50% of the peak load and 50% of the base load.

Because available power in winter is significantly larger, not only PV should be installed, but other renewable sources like wind also have to be considered in Belgium to balance the RES with the loads on a local level.

VI. FUTURE WORK

To calculate the possible increase in renewable sources facilitated solely by DSM, simulations considering the effect on a whole year are necessary. With the loads described in Table 1 a practical test infrastructure is being built at KHKempen to investigate the total potential of DSM for balancing PV power.

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